

Message Text

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PASS TO DOE

E.O. 11652: XGDS-3
TAGS: PARM US UK UR
SUBJECT: CTB NEGOTIATIONS: US PRESENTATION AT TECHNICAL
WORKING GROUP MEETING, FEBRUARY 28

CTB MESSAGE NO. 157

THE FOLLOWING DESCRIPTION OF ISI ARRAYS WAS PROVIDED TO
CTB/ISI TECHNICAL WORKING GROUP BY US DELEGATION, 28 FEB.
TEXT BEING SENT SINCE WE UNDERSTAND WORK IS NOW IN
PROGRESS IN WASHINGTON ON RELATED PROBLEM.

BEGIN TEXT:

TECHNICAL DESCRIPTION AND JUSTIFICATION OF SEISMOMETER
ARRAYS AS INTERNAL SEISMIC INSTALLATIONS

IN SEVERAL PREVIOUS PAPERS PRESENTED TO THIS GROUP
WE HAVE MADE REFERENCE TO INTERNAL SEISMIC ARRAY STATIONS.

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IN THIS PRESENT PAPER, WE PROVIDE A TECHNICAL DESCRIPTION
OF AN EXAMPLE OF AN INTERNAL SEISMIC ARRAY STATION AND
JUSTIFICATIONS FOR THE VARIOUS CONCEPTS WE ARE PUTTING
FORWARD. MANY OF THE TECHNICAL FEATURES OF ARRAY
STATIONS, AND OUR JUSTIFICATIONS FOR THESE FEATURES, ARE
SIMILAR TO THOSE DESCRIBED IN OUR PAPERS ON THREE COMPO-
NENT STATIONS; THEREFORE, THESE SIMILAR FEATURES WILL

NOT BE RE-EXAMINED HERE.

I. JUSTIFICATION OF ARRAY INTERNAL SEISMIC INSTALLATION

THE PURPOSE OF THE DEPLOYMENT OF SEISMOMETERS IN ARRAYS WITHIN THE CONTEXT OF TREATY VERIFICATION IS FOR THE REDUCTION OF SEISMIC NOISE OR IMPROVEMENT IN THE SIGNAL-TO-NOISE RATIO. THESE IMPROVEMENTS PROVIDE INCREASE IN DETECTION AND IDENTIFICATION CAPABILITY AND THEREFORE IMPROVE THE CONFIDENCE OF THE PARTIES IN TREATY COMPLIANCE.

THE SPACING OF THE INDIVIDUAL ARRAY ELEMENTS IS DEPENDENT ON THE NOISE CHARACTERISTICS AT THE PARTICULAR GEOGRAPHICAL LOCATION OF INTEREST. THE OVERALL DIMENSION (OR APERTURE) OF AN ARRAY IS DEPENDENT ON THE WAVELENGTH OF THE SIGNALS OF INTEREST AND ON THE DEGREE TO WHICH SIGNAL COHERENCY IS MAINTAINED OVER THE WHOLE APERTURE. GIVEN THAT THE INDIVIDUAL ARRAY ELEMENTS ARE PROPERLY SPACED, THE SEISMIC NOISE WILL BE INCOHERENT BETWEEN INDIVIDUAL ELEMENTS WHILE THE SEISMIC SIGNALS RECORDED AT THE INDIVIDUAL ELEMENTS WILL BE APPROXIMATELY THE SAME. IF THE SIGNALS FROM ALL THE ARRAY ELEMENTS ARE ALIGNED IN TIME AND SUMMED, THE NOISE ON THE ARRAY SUM WILL BE REDUCED RELATIVE TO THE SIGNAL DUE TO PARTIAL DESTRUCTIVE INTERFERENCE OF THE NOISE FROM THE INDIVIDUAL ELEMENTS.

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IDEALLY, FOR AN ARRAY OF "N" SENSORS, A GAIN IN SIGNAL-TO-NOISE RATIO OF SQUARE ROOT OF "N" IS TO BE EXPECTED. OUR EXPERIENCE HAS SHOWN THAT THE SEISMIC SIGNAL-TO-NOISE RATIO CANNOT BE ARBITRARILY INCREASED BY SQUARE ROOT OF "N" THROUGH INCREASING THE DIMENSIONS AND ELEMENTS OF AN ARRAY. EVENTUALLY, FOR VERY LARGE ARRAYS, THE SEISMIC SIGNALS FROM WIDELY SEPARATED ELEMENTS BECOME DIS-SIMILAR AND NO FURTHER SIGNAL ENHANCEMENT IS REALIZED.

ARRAY INSTALLATIONS PROVIDE THE CAPABILITY TO ESTIMATE THE DIRECTION AND VELOCITY OF SEISMIC WAVE PROPAGATION, WHICH IS EXTREMELY USEFUL IN IDENTIFYING INDIVIDUAL SEISMIC PHASES IN THE COMPLICATED SEISMOGRAMS OBSERVED AT REGIONAL DISTANCES. THROUGH THE PROCESSING OF ARRAY DATA, THE EFFECTS OF A DOMINANT SOURCE OF NOISE OR AN INTERFERRING SEISMIC EVENT CAN BE MINIMIZED. FOR EXAMPLE, A COHERENT SOURCE OF NOISE ACROSS THE ARRAY CAN BE MINIMIZED WITH LITTLE SIGNAL DISTORTION USING ARRAY PROCESSING TECHNIQUES.

FINALLY, THE CHOICE OF THE FREQUENCY BAND FOR EACH ELEMENT OF AN ARRAY IS DICTATED BY THE LOCATION OF THE

ELEMENT WITHIN THE ARRAY PATTERN. THUS, FOR AN ARRAY DESIGNED TO ACCEPT THE ENTIRE SEISMIC SPECTRUM OF INTEREST, THE INDIVIDUAL ARRAY ELEMENTS WILL BE JUST A SUBSET SELECTED FROM THE THREE-COMPONENT STATION WE HAVE ALREADY DESCRIBED. THE ONLY NEW EQUIPMENT IN AN ARRAY INSTALLATION NOT INCLUDED IN OUR DESCRIPTION OF THE THREE COMPONENT STATION IS THAT TO HANDLE THE MULTI-CHANNEL ASPECTS OF AN ARRAY: THE NECESSARY INTERFACES BETWEEN THE ELEMENTS AND THE CENTRAL ARRAY FACILITY.

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II. GENERAL DESCRIPTION

BASED ON OUR EXPERIENCE, THE EXAMPLE OF THE INTERNAL ARRAY STATION CONSISTS OF 25 INDIVIDUAL ELEMENTS WHERE SEISMOMETERS ARE EMPLACED. THREE ORTHOGONAL COMPONENTS OF LONG PERIOD EARTH MOTION WOULD BE MEASURED AT 6 OF THESE ELEMENTS. SHORT PERIOD MOTION IN THE VERTICAL DIRECTION WOULD BE MEASURED AT 18 ELEMENTS, ABOUT 6 OF WHICH WOULD ALSO MEASURE VERTICAL EARTH MOTION IN THE MID-PERIOD RANGE. AT THE REMAINING ELEMENT THREE ORTHOGONAL COMPONENTS OF EARTH MOTION WOULD BE RECORDED IN THE LONG, SHORT, AND MID-PERIOD RANGES AND VERTICAL GROUND MOTION WOULD BE MEASURED IN THE HIGH FREQUENCY BAND. ALL SEISMOMETERS WOULD BE EMPLACED IN 100 METER BOREHOLES WITH ASSOCIATED ELECTRONICS SIMILAR TO THOSE DESCRIBED IN OUR PRESENTATIONS ON INTERNAL SEISMIC STATIONS. OUR EXPERIENCE HAS SHOWN THAT HEXAGONAL ARRAY DEPLOYMENT PATTERNS ARE DESIRABLE. DATA FROM THE INDIVIDUAL ARRAY ELEMENTS WOULD BE TRANSMITTED TO A NEARBY CENTRAL

ARRAY FACILITY (DENOTED AS ARRAY PROCESSING STATION IN THE TREATY LANGUAGE) FOR COMBINATION AND RETRANSMITTAL TO THE PARTIES SIMULTANEOUSLY.

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III. DESCRIPTION OF THE BOREHOLE PACKAGE

A. SEISMOMETERS. THE SEISMOMETERS USED WOULD BE SIMILAR TO THOSE AS DESCRIBED IN OUR PREVIOUS PAPERS. THE BROAD-BAND MODIFIED SEISMIC RESEARCH OBSERVATORY SEISMOMETER COULD BE USED AT THOSE ELEMENTS WHERE DATA ARE REQUIRED FROM LONG PERIOD OR MID-PERIOD AND SHORT PERIOD RANGES. AT ELEMENTS WHERE ONLY SHORT PERIOD DATA ARE REQUIRED, A SEISMOMETER SIMILAR TO THE SHORT PERIOD SEISMOMETERS FOR THE THREE COMPONENT STATION WOULD BE USED. AT ONE REMOTE ARRAY ELEMENT, THE SEISMOMETER CONFIGURATION WILL BE IDENTICAL TO THAT OF THE THREE-COMPONENT STATION. BECAUSE OF THE LARGE NUMBER OF ELEMENTS IN AN ARRAY, BACK-UP SEISMOMETERS SHOULD NOT BE REQUIRED IN EACH BOREHOLE.

THE JUSTIFICATION FOR THESE TYPES OF SEISMOMETERS IS THE SAME AS GIVEN PREVIOUSLY. THREE COMPONENT LONG PERIOD DATA IS INCLUDED BECAUSE OF ITS USEFULNESS IN SOURCE IDENTIFICATION. THE HORIZONTAL COMPONENTS OF SHORT AND MID-PERIOD DATA ARE NOT NECESSARY FROM ALL ARRAY ELEMENTS BECAUSE OF THE DIRECTIONAL AND SIGNAL ENHANCEMENT CHARACTERISTICS OF ARRAYS AND THE LARGE DATA TRANSMISSION CAPACITY THAT WOULD BE REQUIRED.

B. FILTERS AND AMPLIFIERS. SPECTRAL SHAPING OF SEISMOMETER OUTPUTS WOULD BE ACCOMPLISHED BY ANALOG FILTERS. THE SPECTRAL SHAPING WOULD PROVIDE A MAXIMUM RESPONSE TO EARTH MOTION IN THE FOLLOWING FREQUENCY BANDS:

LONG PERIOD (LP) .01 HERTZ TO 0.1 HERTZ
..... 7 ELEMENTS, 3 ORTHOGONAL AXES

MID-PERIOD (MP) .07 HERTZ TO 1.0 HERTZ
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..... 6 ELEMENTS, VERTICAL AXIS
..... 1 ELEMENT, 3 ORTHOGONAL AXES

SHORT PERIOD (SP) 0.5 HERTZ TO 6 HERTZ
..... 18 ELEMENTS, VERTICAL AXIS

..... 1 ELEMENT, 3 ORTHOGONAL AXES

HIGH FREQUENCY (HF) 4.0 HERTZ TO 10-20 HERTZ

..... 1 ELEMENT, VERTICAL AXIS

THE JUSTIFICATION FOR THESE FREQUENCY BANDS HAS BEEN
GIVEN IN OUR PREVIOUS PAPERS.

C. ANALOG-TO-DIGITAL UNIT. THE TECHNICAL DESCRIPTION
AND JUSTIFICATION FOR THIS UNIT ARE THE SAME AS PREVIOUSLY
STATED. DATA FORMATS AT THE ARRAY REMOTE ELEMENTS WOULD
BE CHANGED FROM THOSE DESCRIBED FOR A SINGLE STATION TO
REFLECT THE RELATIVELY LOWER SEISMIC DATA VOLUME FROM
ARRAY REMOTE ELEMENTS.

D. STATE-OF-HEALTH AND TIMING. THE TECHNICAL DESCRIPTION
AND JUSTIFICATION OF THE STATE-OF-HEALTH MODULES ARE
THE SAME AS PRESENTED FOR A SINGLE STATION. TIMING COULD
BE PROVIDED IN EACH ARRAY REMOTE ELEMENT BOREHOLE PACKAGE
OR FROM A CENTRAL FACILITY.

E. AUTHENTICATOR. THE TECHNICAL DESCRIPTION AND JUSTIFICATION
FOR THE AUTHENTICATOR ARE THE SAME AS BEFORE;
HOWEVER, AUTHENTICATION MAY NOT BE REQUIRED AT ALL ARRAY
REMOTE ELEMENTS.

F. BOREHOLE SYSTEM CONTROL. THIS UNIT WOULD PERFORM

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CALIBRATION AND OTHER FUNCTIONS AS DESCRIBED IN PREVIOUS PAPERS.

IV. REMOTE SITE SURFACE EQUIPMENT

A. REMOTE SITE COMMUNICATION UNIT. THIS SURFACE UNIT WOULD RECEIVE DATA FROM THE BOREHOLE PACKAGE AND FORWARD THOSE DATA TO THE CENTRAL ARRAY FACILITY. ITS SPECIFIC DESIGN DEPENDS UPON THE NATURE OF THE INTRA-ARRAY COMMUNICATIONS SYSTEM, WHICH IN TURN MAY BE DICTATED BY TERRAIN OR OTHER CONSIDERATIONS.

B. REMOTE SITE POWER UNIT. POWER SOURCES WILL BE REQUIRED AT EACH REMOTE ELEMENT TO OPERATE BOREHOLE PACKAGE AND THE REMOTE ELEMENT COMMUNICATIONS UNIT.

V. INTRA-ARRAY COMMUNICATIONS SYSTEM

TWO-WAY COMMUNICATION LINKS MUST BE ESTABLISHED AND MAINTAINED BETWEEN THE INDIVIDUAL REMOTE ELEMENT AND THE
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CENTRAL ARRAY FACILITY. THIS COULD BE ACCOMPLISHED EITHER THROUGH THE USE OF RADIO TELEMETRY, LAND MINES, OR A COMBINATION OF BOTH. LOCAL TERRAIN AND GROUND SURFACE CONDITIONS ARE FACTORS THAT WOULD HAVE TO BE TAKEN INTO CONSIDERATION IN THE SPECIFICATION OF THE INTRA-ARRAY COMMUNICATIONS SYSTEM.

THIS COMMUNICATIONS SYSTEM IS JUSTIFIED BY THE REQUIREMENT TO COLLECT ALL OF THE SEISMIC AND STATE-OF-HEALTH DATA FROM REMOTE ELEMENTS AT A CENTRAL FACILITY AND TO SEND CALIBRATION AND OTHER COMMANDS FROM THE CENTRAL FACILITY TO THE REMOTE ELEMENTS.

VI. CENTRAL ARRAY FACILITY

A CENTRAL ARRAY FACILITY SHOULD BE LOCATED WITHIN A FEW TENS OF KILOMETERS FROM THE ARRAY AND AT LEAST AS FAR AWAY FROM INDIVIDUAL ARRAY ELEMENTS TO MINIMIZE THE SEISMIC EFFECTS OF ACTIVITY ASSOCIATED WITH THE OPERATION OF THE ARRAY. ITS SPECIFIC DESIGN WOULD BE AGREED TO BY THE PARTIES.

A CENTRAL ARRAY FACILITY SHOULD INCLUDE THE FOLLOWING REQUIRED FUNCTIONS, WHICH ARE JUSTIFIED IN TERMS OF THE NECESSARY ARRAY DATA ORGANIZATION AND TRANSMISSION ACTIVITIES:

A. RECEIVE REAL-TIME DATA FROM THE INDIVIDUAL REMOTE ELEMENTS.

B. COMBINE AND RETRANSMIT IN NEAR REAL-TIME DATA FROM THE INDIVIDUAL REMOTE ELEMENTS TO THE PARTIES SIMULTANEOUSLY, VIA INTELSAT OR OTHER EQUIVALENT COMMUNICATIONS LINK. THE DESIGN OF THE ARRAY COMMUNICATION TERMINAL
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WOULD BE SIMILAR TO THAT DESCRIBED FOR THE THREE COMPONENT STATION, BUT WITH ADDED CAPACITY TO ACCOMMODATE THE HEAVIER DATA TRANSMISSION LOAD.

C. RECEIVE AND FORWARD COMMANDS FOR REMOTE ELEMENTS.

D. PROVIDE BACK-UP RECORDING IN CASE OF FAILURE OF THE NEAR REAL-TIME COMMUNICATIONS LINK.

VII. ARRAY GEOMETRY

AN EXAMPLE OF OUR CONCEPT OF A GEOMETRY APPROPRIATE FOR AN INTERNAL ARRAY STATION IS SHOWN IN FIGURE 1. OUR EXPERIENCE HAS SHOWN THAT HEXAGONAL ARRAY ELEMENT PATTERNS ARE DESIRABLE BECAUSE THEY RESULT IN REGULAR ARRAY RESPONSE PATTERNS AND BECAUSE THEY ALLOW FOR A RELATIVELY HIGH DENSITY OF INSTRUMENTS WITHIN RELATIVELY SMALL DIMENSIONS. THE ACTUAL SPACING OF ARRAY ELEMENTS WILL BE DETERMINED BY LOCAL NOISE CONDITIONS AND THE WAVELENGTHS OF INTEREST. A LIKELY SPACING OF ARRAY ELEMENTS WOULD BE AS FOLLOWS: SHORT PERIOD ELEMENTS, 2-4 KILOMETERS, MID-PERIOD ELEMENTS 408 KILOMETERS, LONG PERIOD ELEMENTS 20-30 KILOMETERS. IN PRACTICE, TERRAIN, COMMUNICATION, AND DRILLING CONDITIONS MAY REQUIRE SOME DEVIATIONS FROM THE IDEAL SPACING AND GEOMETRY. END TEXT. WARNKE

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